

Con-X Microcalorimeter Development at NIST

The NIST X-ray Team

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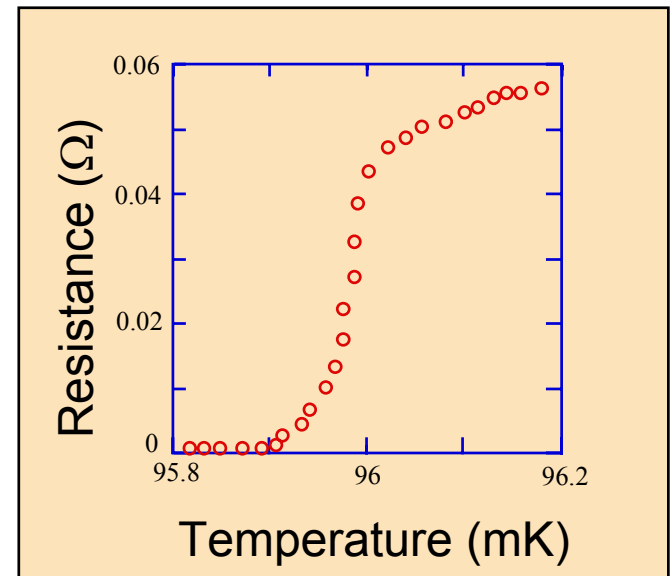
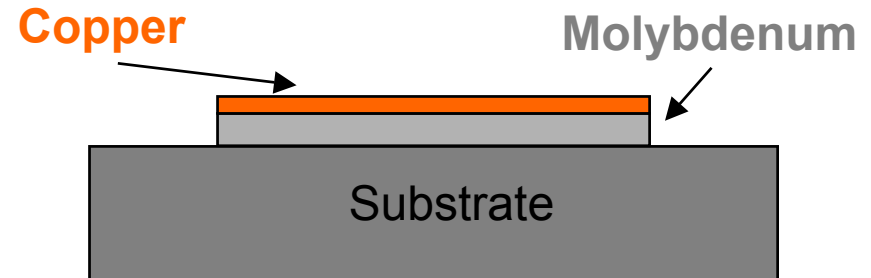
Fabrication status

- Problems with transition-temperature reproducibility over the last year: resolved with single-application deposition system
- Benzotriazole Cu passivation step implemented
- Square geometry TES microcalorimeters fabricated
- Several varieties of annular-geometry detectors fabricated
- Mo and Al films implanted with magnetic ions - a possible alternative to bilayers
- Surface-micromachined structures for arraying - ready to begin test array fabrication

Mo-Cu and Mo-Au Bilayer TES

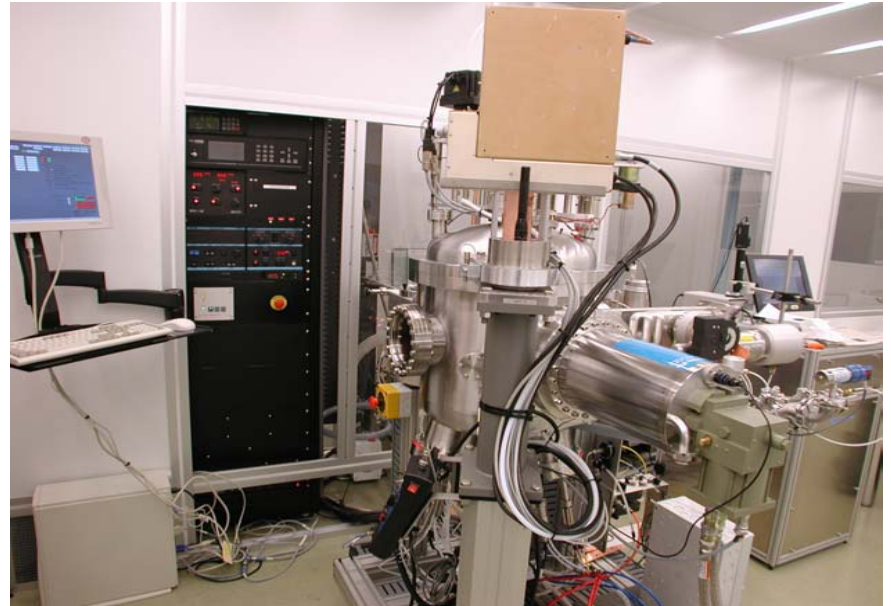
- A bilayer of a thin superconducting film and a thin normal metal acts as a single superconductor with a tunable T_c - the “proximity effect”
- Mo-Cu and Mo-Au
Robust and temperature stable
Molybdenum $T_c \sim .92\text{ K}$
Copper, Gold *normal*

- Sharp
- Reproducible
- Tunable
- Robust



Dedicated Mo-Cu bilayer system

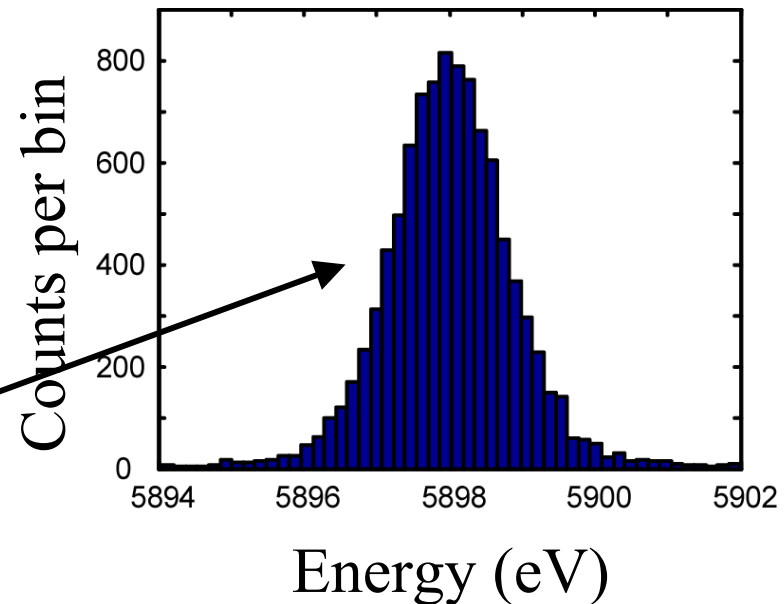
- Fully automated, load-lock sputtering system
- Single application / controlled access
- Has resolved problems with process drift
- Uniform films over whole wafer ($\sim 1\%$)
- Reproducible, uniform transition temperatures



New square geometry detectors

- 400 μm \times 400 μm pixel
- Operate up to ~ 10 keV
- Mistake on 3- μm Bi absorber (thick layer of contaminants between the TES and the Bi). New detectors in fab. Good thermalization at low energy, *significant* excess broadening at 6 keV
- 5.9 keV heat pulses ~ 2 eV FWHM calibrated against x-rays (does **NOT** include thermalization broadening!!)

Remember,
Just a heat pulse

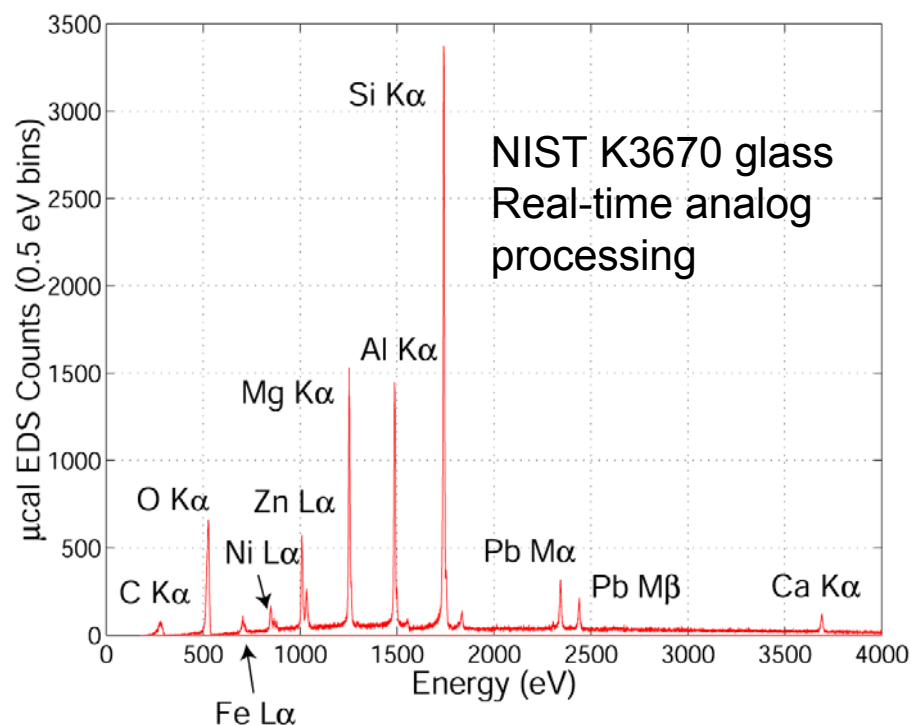


Microcalorimeter system transferred to Gaithersburg



X-ray
microcalorimeter

SEM



In active use by *chemists* in the Chemical
Science & Technology Lab at NIST
(Dale Newbury *et. al.*)

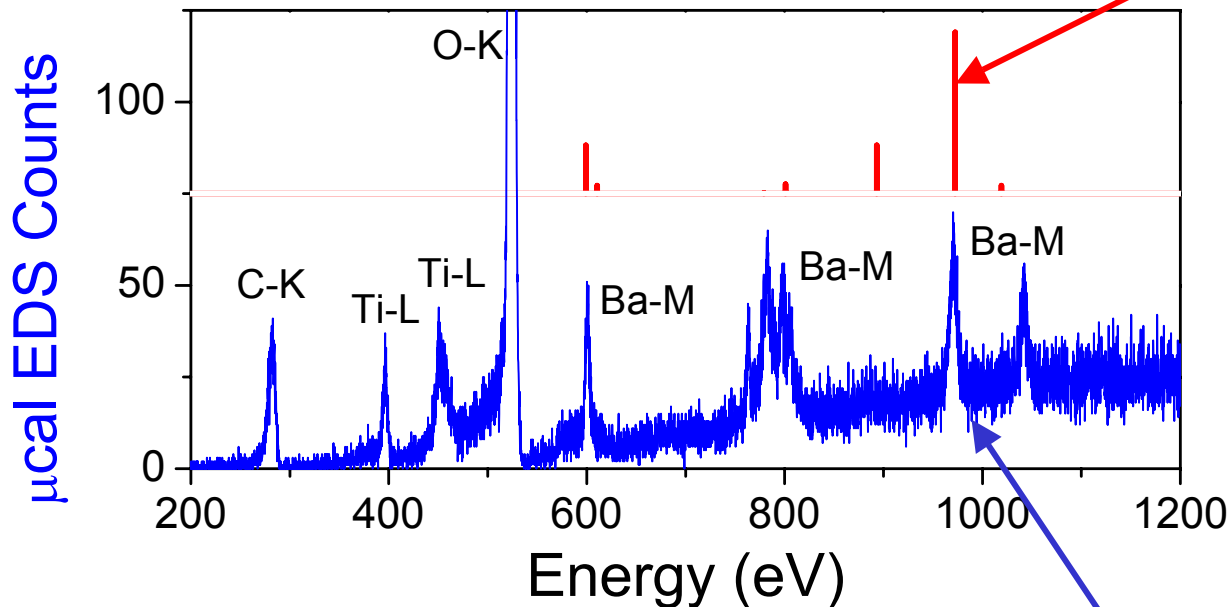
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Survey of L,M lines of heavy elements

A TES microcalorimeter system is now being used by NIST to tabulate new values of the L&M lines of the heavy elements. Currently tabulated values are extremely inaccurate.



Tabulated Ba M line positions and intensities

Example: Ba M lines measured using a TES microcalorimeter disagree with tabulated values. Microcalorimeter results were verified with a WDS crystal spectrometer.

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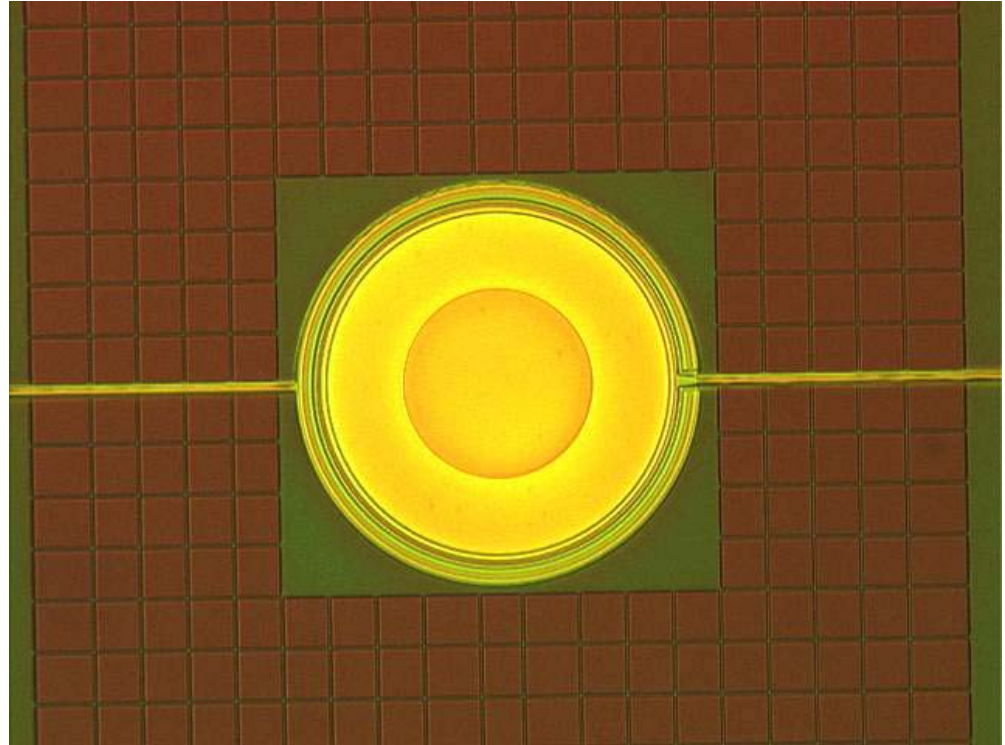
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TES microcalorimeter data



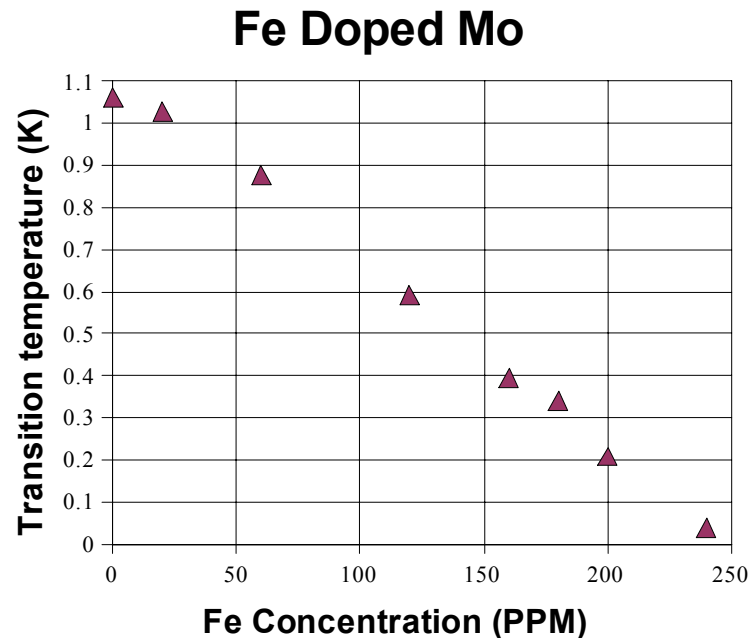
Annular TES design

- Radial symmetry
- No boundaries parallel to current flow
- Magnetically self shielded
- Will have different noise characteristics
- Several varieties fabricated, already showed enhancement of critical current, awaiting testing as spectrometers

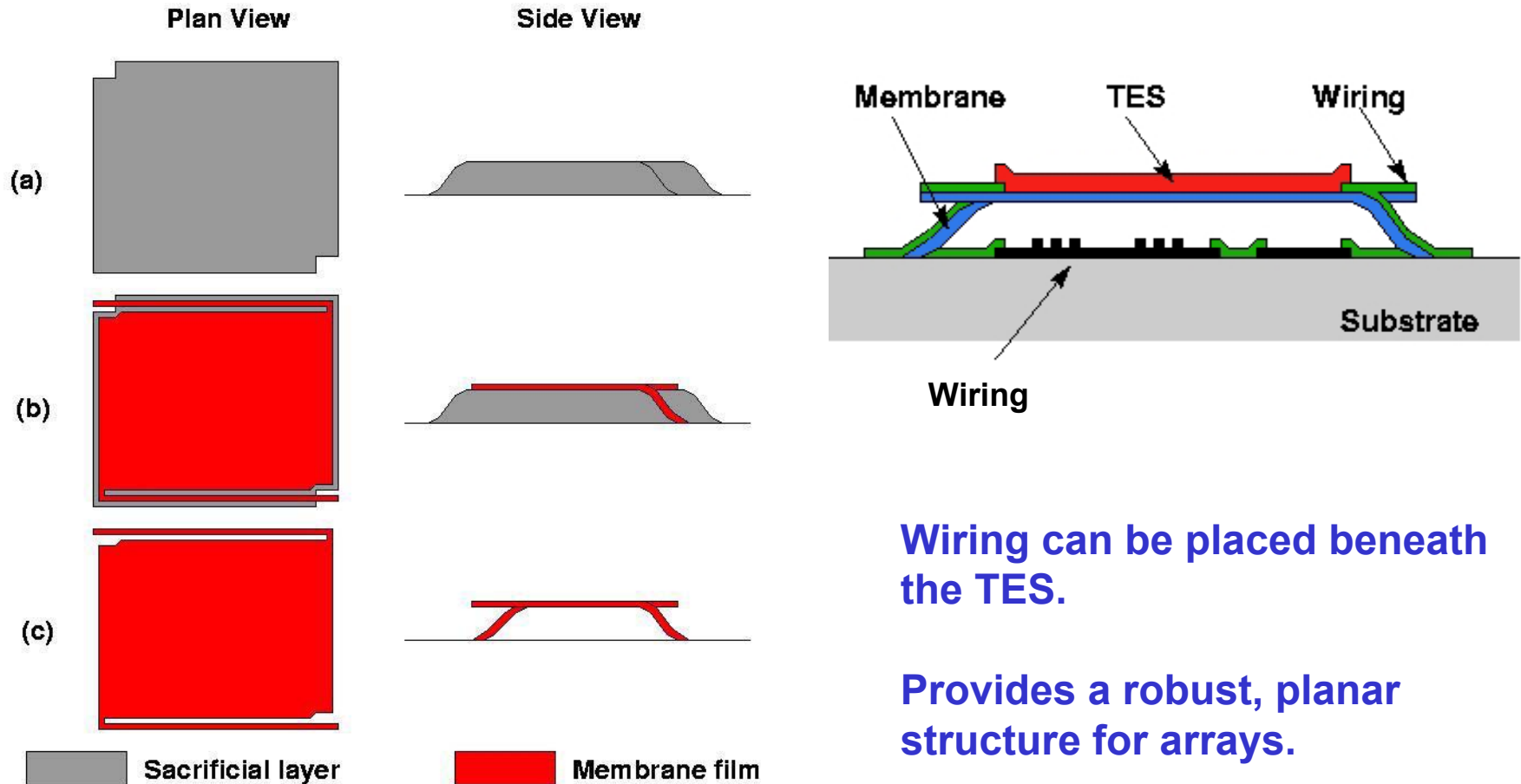


Magnetic impurity TES

- Reduction of T_c using ion implanted magnetic ions.
- Have implanted Fe, Co, Gd, Mn into Mo and Al.
- Potential simpler processing
- Different optimization parameter space



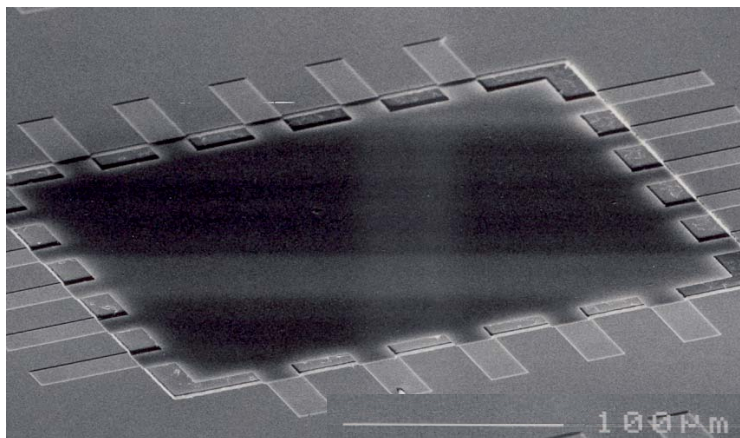
Surface-micromachined microcalorimeters



Wiring can be placed beneath the TES.

Provides a robust, planar structure for arrays.

Surface micromachined structures



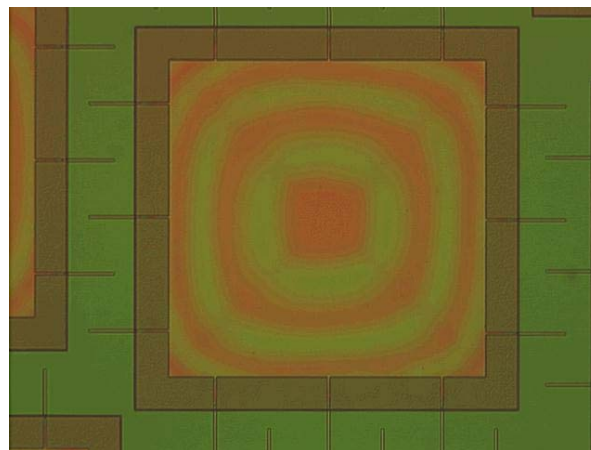
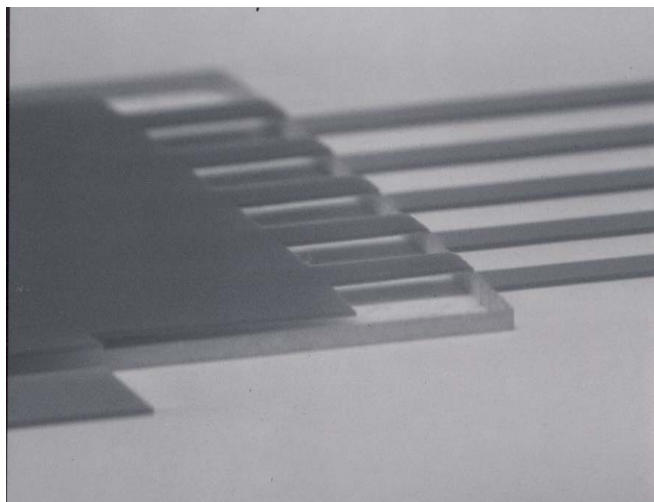
Fabrication:

Release layer - 2 μm polysilicon

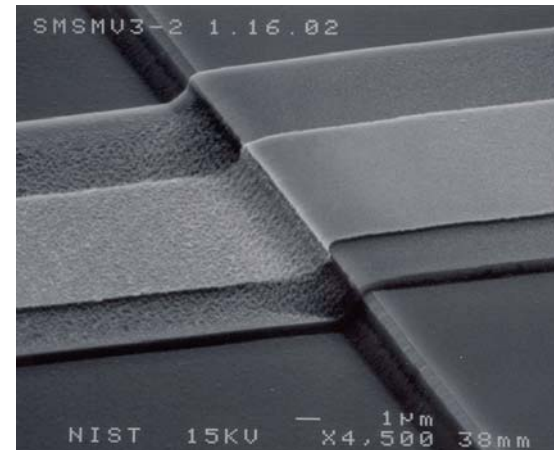
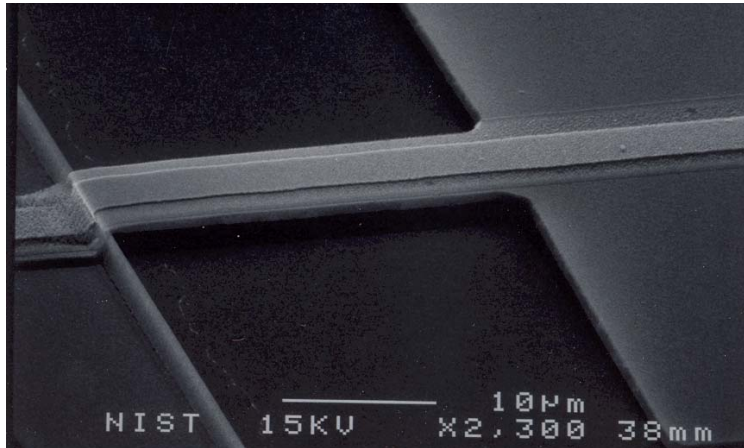
Release - XeF_2 isotropic dry etch

Membrane - 0.5 μm low stress nitride

Wiring - 200 nm sputtered Mo on top,
Nb underneath

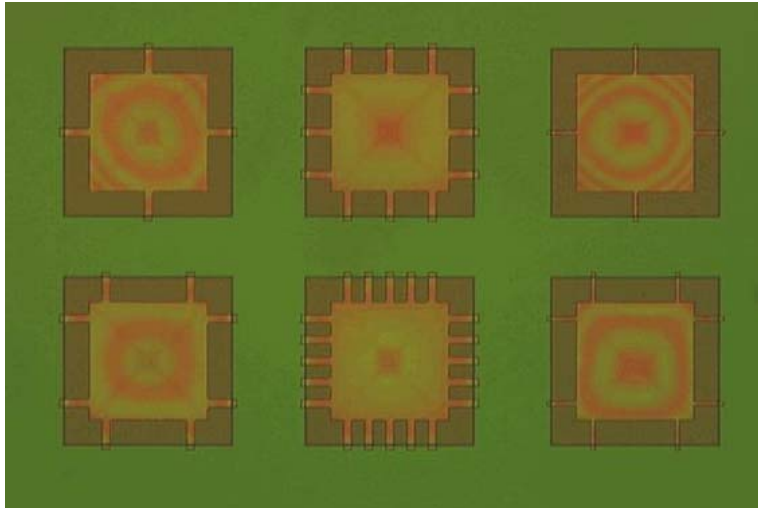


Wiring and surface micromachining

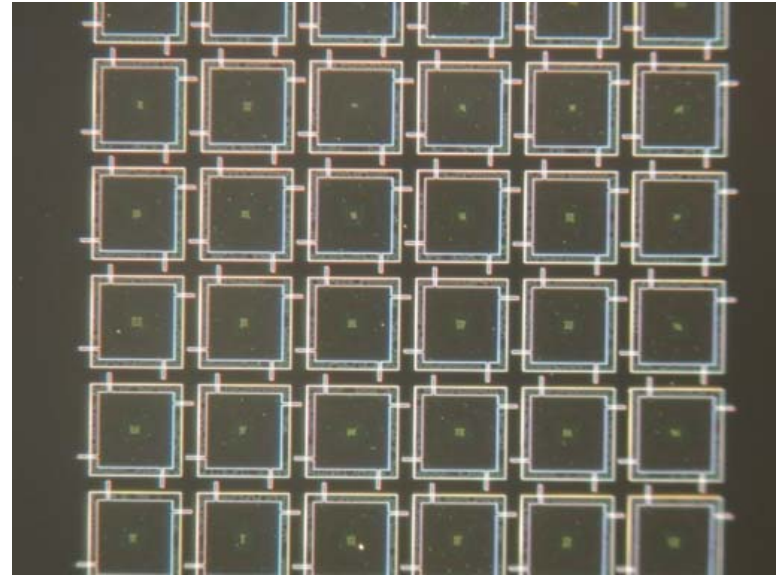


- Demonstrated superconducting Mo wires running up on platform (to connect pixels)
- Demonstrated superconducting Nb wires running beneath platform (to extract leads from focal plane)

Arrays by surface micromachining



Probing different leg structures



6×6 array of 250 μm micromachined structures for TES

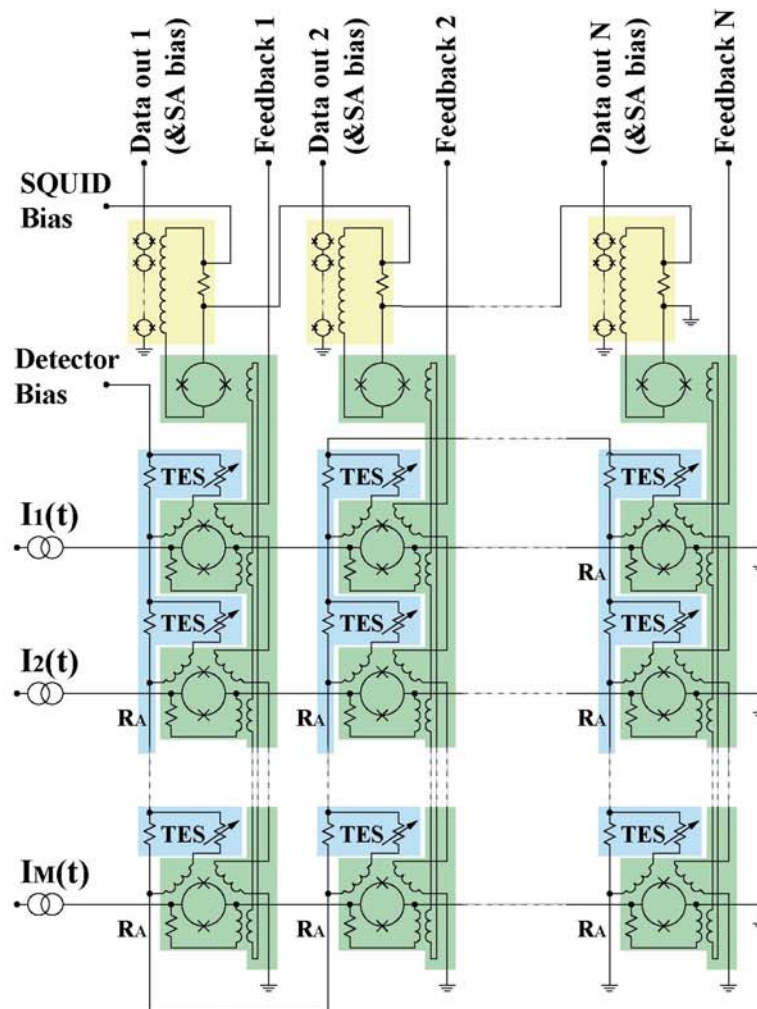
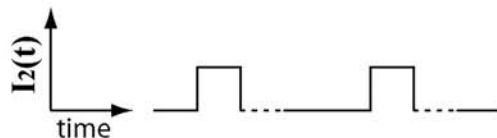
Instrumentation Status

- 32-channel SQUID multiplexer demonstrated at 4 K
- Room-temperature electronics for 2×8 demo in place
- Firmware and software for switched digital feedback tested
- Initial multichip ADR MUX boards fabricated
- ADR wired with Cu-Ni flex cabling and SQUID modules for 2×8 demonstration array
- Beginning design of common 2×8 platform with GSFC - *will allow GSFC-NIST exchange of devices.*

SQUID multiplexer scheme

Boxcar Modulation Functions

(can be from Cryogenic CMOS MUX)

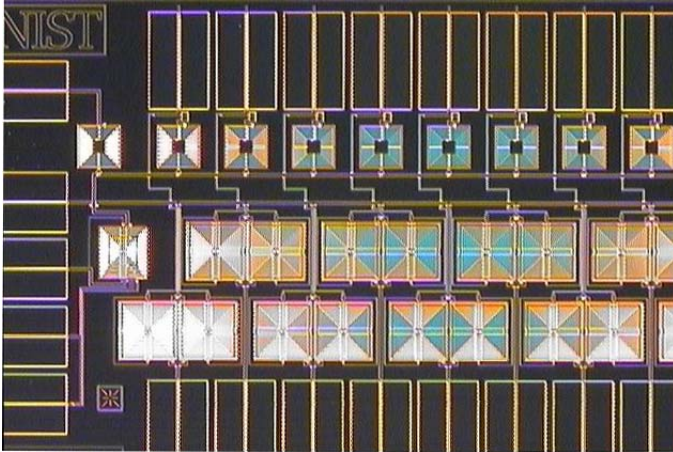


Series Array SQUID (4K)

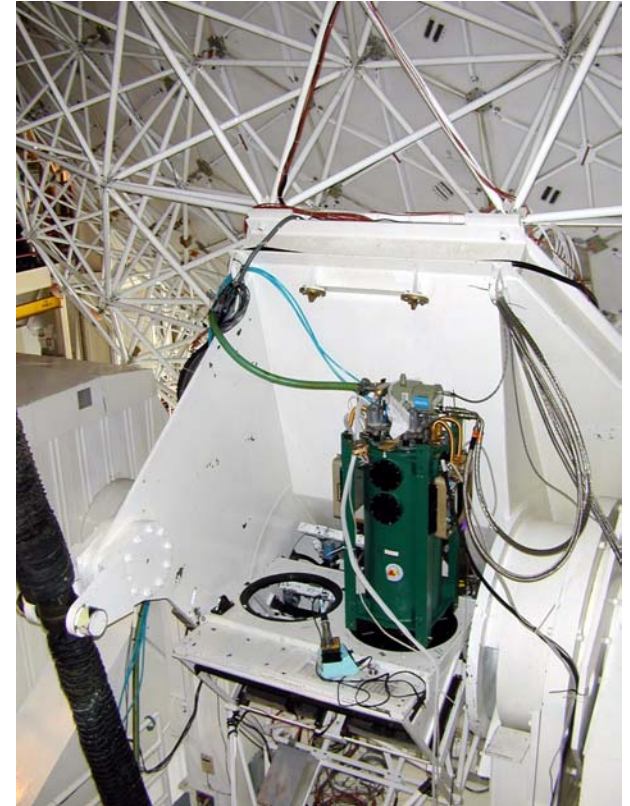
Multiplexer chip(s)

Detector chip(s)

SQUID MUX

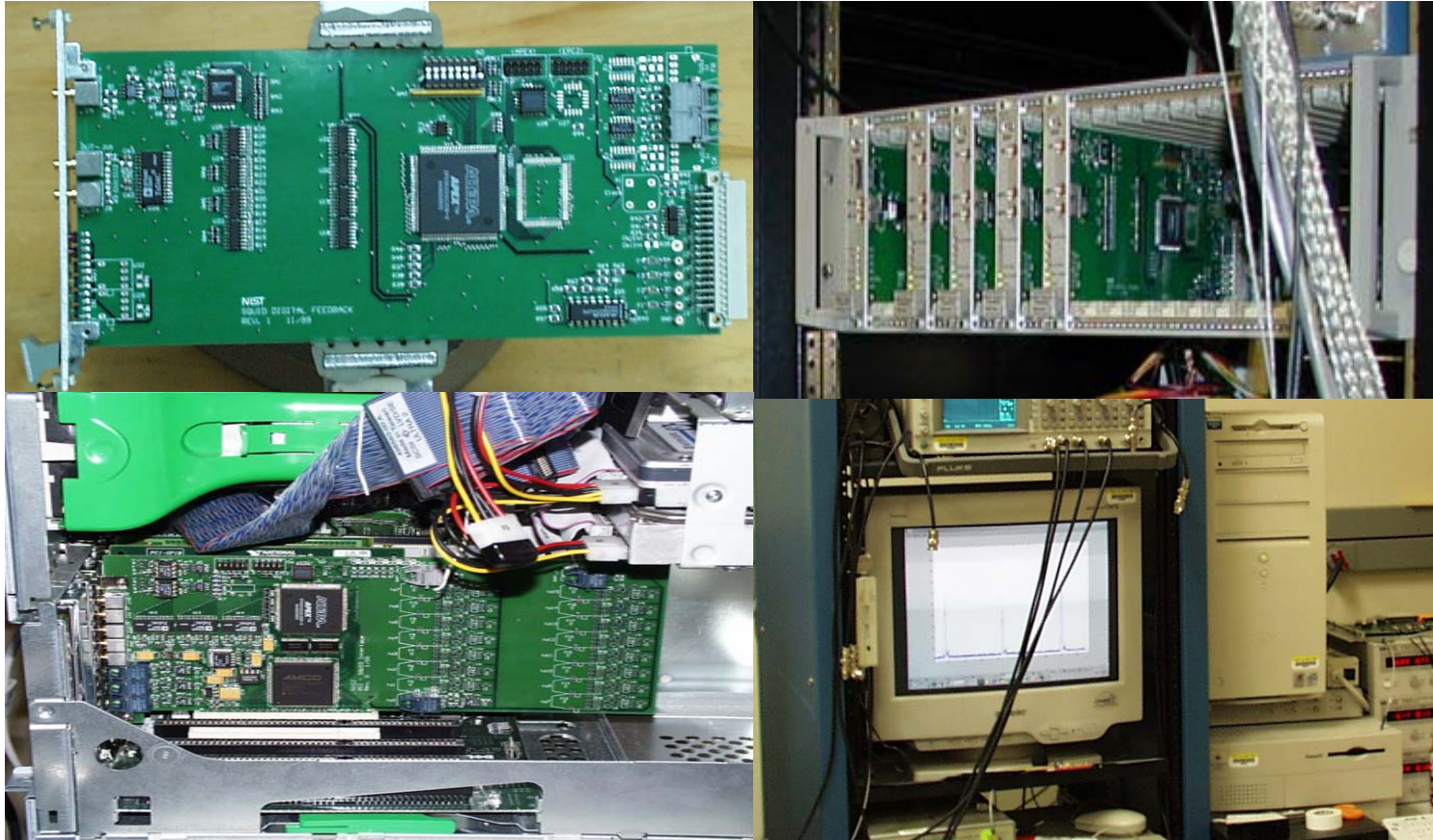


- 32-channel MUX. (Need 32 chips to instrument kilopixel array.)
- First-generation MUX deployed in astronomical instrument (FIBRE) with Dominic Benford *et. al.* at GSFC
- Second generation improves crosstalk & power



FIBRE at the CSO

Room-temperature MUX electronics



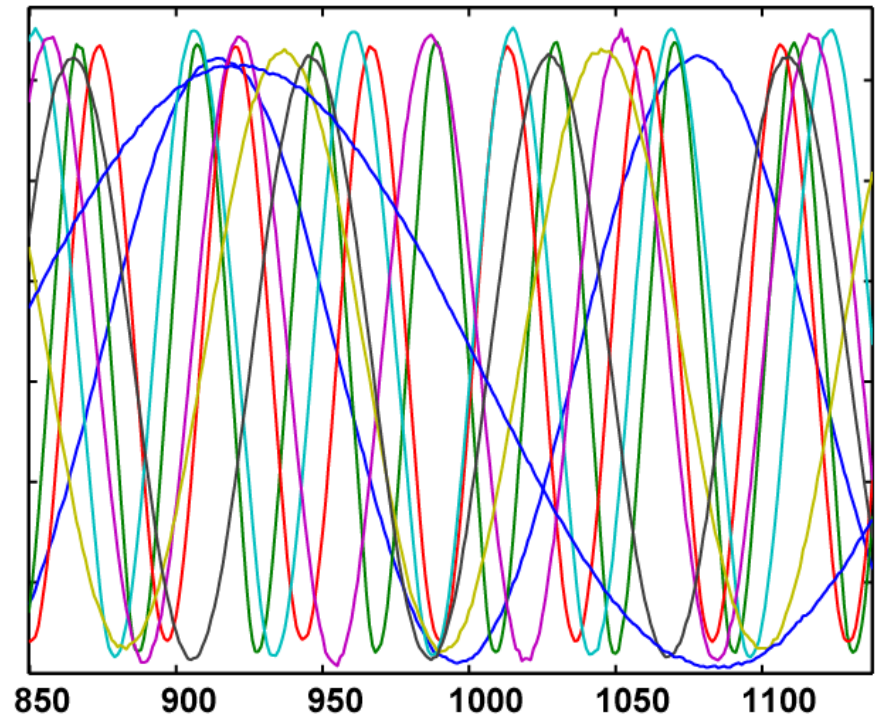
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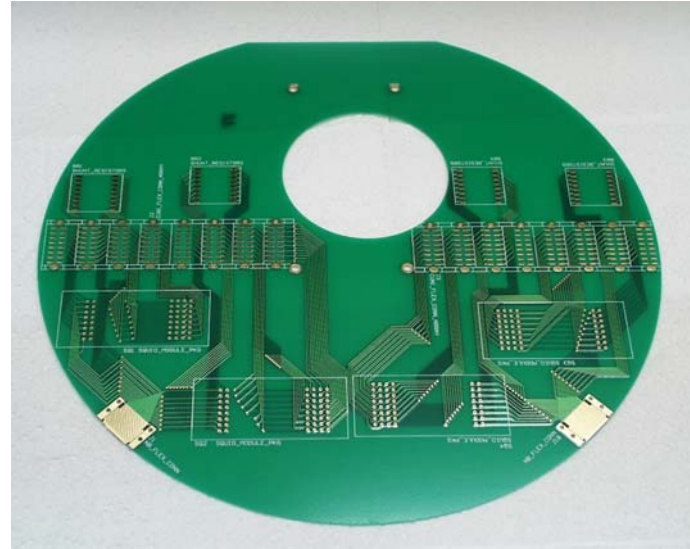
FPGA firmware for switched feedback

- Switched digital feedback is working
- Can sample at 1.6 MHz line rate
- Sufficient performance for 2×8 demo array
- Need to increase bandwidth for full instrument



Different sinewaves in 8 SQUIDs

Instrumentation Status



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Six-month plan

- 1) Characterize performance of existing square detectors
- 2) Fabricate and test square detectors with better Bi absorbers
- 3) Fabricate TES detectors using Fe-implanted Mo.
- 4) Fabricate a small array of TES detectors using surface-micromachined structures
- 5) Test annular detectors
- 6) Design common 2 x 8 platform with GSFC